



RDECOM

IMX-104 Characterization for DoD Qualification



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Insenitive Munitions & Energetic Materials Technology Symposium

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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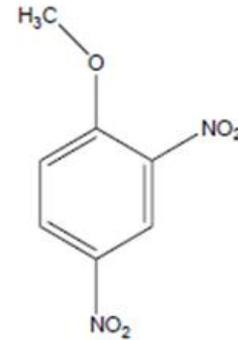


- **PM CAS initiated Common Low-cost Insensitive Munitions Explosive Program**
 - **Affordable TNT and Comp B Replacement for near term insertion**
 - Goal 1 - Select one common candidate to replace both
 - Goal 2 - Select one candidate for TNT and one for Comp B energy levels
 - **Results**
 - IMX-101 selected as TNT replacement
 - IMX-104 selected as Comp B replacement

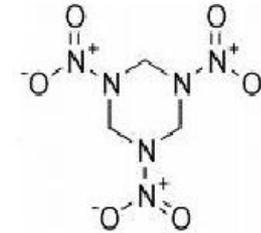
- **Overall Program Objectives**
 - **Provide an insensitive replacement for Comp B with equivalent performance**
 - **Provide characterization data to support the qualification of IMX-104 for full use in Army and USMC ammunition**
 - **Implement IM Solution in 81mm, 60mm & 120mm Mortars**

➤ IMX-104 Formulation

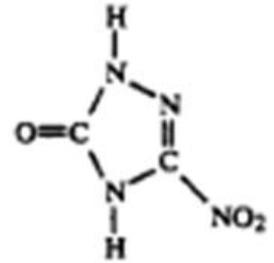
- 2,4-Dinitroanisole (DNAN)
- 3-Nitro-1,2,4-triazol-5-one (NTO)
- RDX



DNAN



RDX



NTO



➤ DoD Energetic Materials Qualification Process

Test Protocol: (1) Allied Ordnance Publication Seven (AOP-7) (Edition 2 Rev. 3), “Manual of Data Requirements and Tests for the Qualification of Explosive Materials for Military Use”, December 2007.

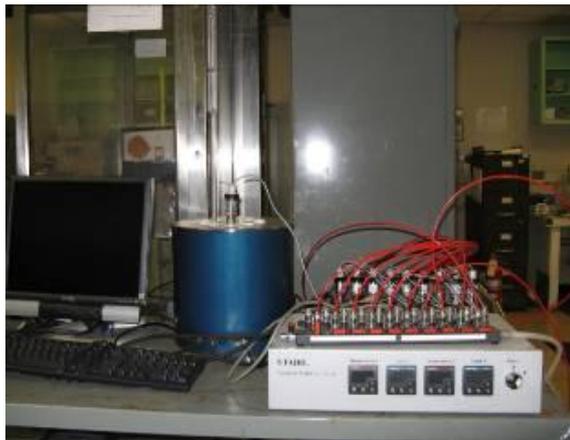
(2) Standardization Agreement (STANAG) 4170 (Edition 3), “Principles and Methodology for the Qualification of Explosive Materials for Military Use”, 2007.

(3) DoD Energetics Qualification Program Matrix for Main Charge Explosives

(4) NAVSEAINST 8020.5C

- Comprehensive assessment of the Energetic Material
 - Safe and Suitable for the intended use
 - Test Protocols Coordinated with NOSSA
 - Single lot tested (unless noted)
 - **IMX-104 Lot# BAE09E408-003**

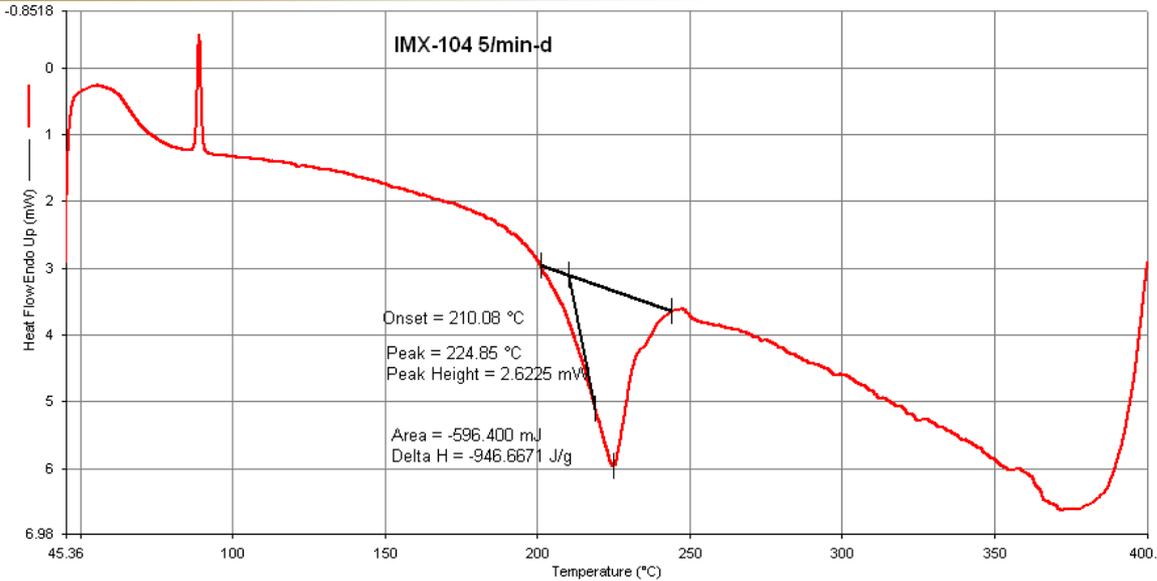
TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULTS (PAX-21 AND COMP B)
Vacuum Thermal Stability (VTS or MVTs)	MIL-STD-1751A (1061 or 1063) Or STANAG 4556	5.00±0.05g 100 °C/48 h Or 100 °C/40 h	≤ 2 ml/g of gas evolved	0.571 ml/g (100 °C/40 h)	PAX-21: 0.18 ml/g Comp B: 0.602 ml/g
Thermal Stability at +75 °C	TB 700-2 UN Test 3c	50g 75 °C/48 h	Evidence of Self Heating	No Reaction	PAX-21: No Reaction Comp B: No Reaction



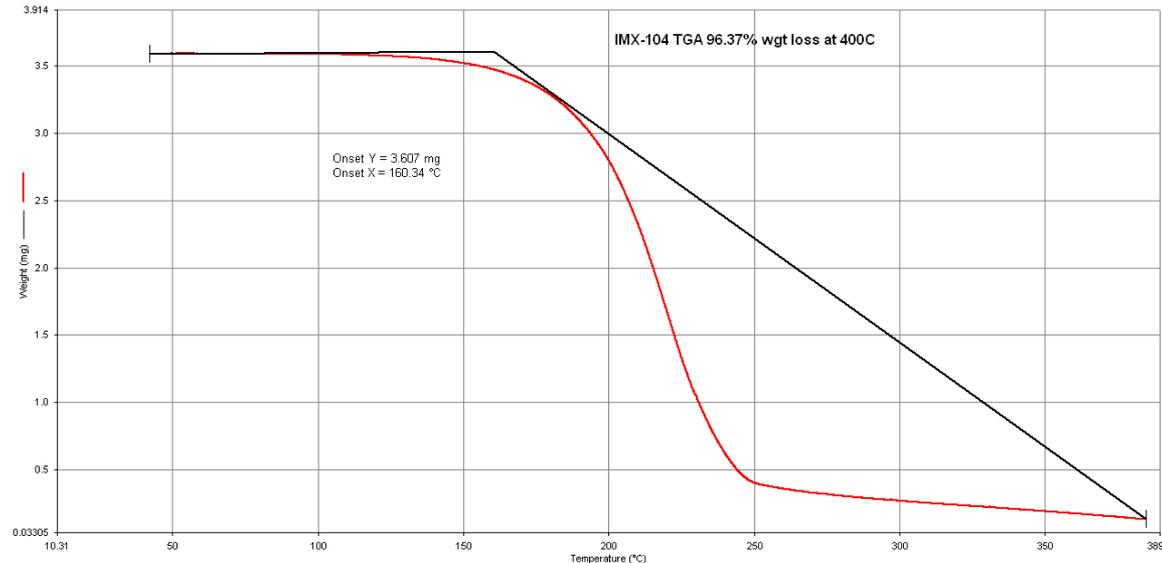
- IMX-104 VTS compatibility tested with all mortar system components
- ALL MATERIALS COMPATIBLE

TEST TITLE	TEST METHOD	TEST CONDITION	TEST RANGE OR LIMIT	TEST RESULT	REFERENCE RESULTS (PAX-21 AND COMP B)
DSC	MIL-STD-1751A (1072) Or STANAG 4515	20 mg 10 °C/min	Endotherm(s): Exotherm(s): Onset Temp. Peak Temp.	Endotherm: 89°C Exotherm: Onset: 212 °C Peak: 224.89°C	PAX-21: Endotherm: Exotherm: Onset: 190 °C Peak: 195 °C Comp B: Endotherm: 75°C Exotherm: Onset: 202.14 °C Peak: 228.66 °C NTO: Endo: -- °C Exo: 278.6 °C DNAN: Endo: 95 °C Exo: >300 °C
TGA	STANAG 4515	5 °C/min	Significant weight loss should be consistent with decomposition temperatures provided by DSC at 5 °C/min	96% weight loss at 400°C	PAX-21: Negligible weight loss @ 192.6°C Comp B: 93% weight loss after decomposition

IMX-104 DSC



IMX-104 TGA

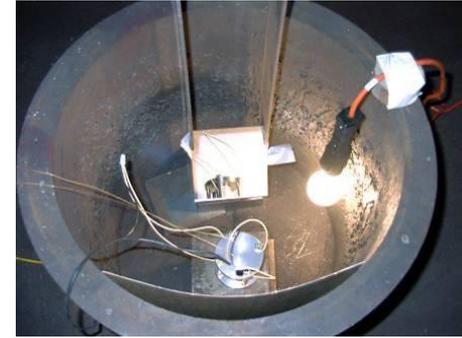


One Liter Cook-off Test

- Sample is heated from melt point at 3.3 °C/hr until decomposition
- Minimum margin of safety for processing is $T_c \geq 30^\circ \text{C}$ above desired processing temperature
 - Non-catastrophic self heating
 - 142°C - 144°C
 - Catastrophic self heating or Critical Temperature
 - $T_c = 161^\circ \text{C} - 163^\circ \text{C}$
- IMX-104 processing
 - 96°C - 99°C



➤ **Acceptable processing Safety margin**



- **Slow Cook-Off (SCO)**
 - Conditioned at 200°F for 2 hours
 - 6°F / hr increase in temperature until reaction
- **Results**
 - T-75: deflagration
 - T-90: deflagration
 - T-105: deflagration
 - T-120: pressure rupture



T-75



T-90



T-105



T-120

- **PAX-21**
 - T15 & T30: Explosion
- **Comp B**
 - T15: Explosion
 - T30: Explosion
 - T90: Explosion
 - T120: Detonation

PAX-21
T15 & T30: Explosion

- **Fast Cook-Off (SCO)**

- Start at ambient temperature
- Increase as quickly as possible with available heater band

Test	1	2	3	4
Confinement	75	90	105	120
Weight	61.69g	61.59g	62.28g	62.36g
Reaction Temp	442 F	415 F	435 F	436 F
Ambient Temp	NA	NA	NA	NA
Time	8 min	7 min	9 min	10 min
Reaction Type	Burn	Burn	Pressure Rupture	Pressure Rupture



T-75



T-90



T-105



T-120

- 50% point between “go” and “no go”
 - Lot BAE09E408-003 baseline ($\rho=1.75$)
 - 106 cards (32.5 kbar)
 - Multiple BAE Holston batches
 - 120.5 cards (average)

Batch Number	LSGT (50% Card Gap)
IMX104-1	123.5
IMX104-2	121.5
IMX104-3	122
IMX104-4	115.5
IMX104-5	125.5
IMX104-6	119
IMX104-27	111
IMX104-46	117.5
IMX104-48	120.5
IMX104-54	127
IMX104-50A	119



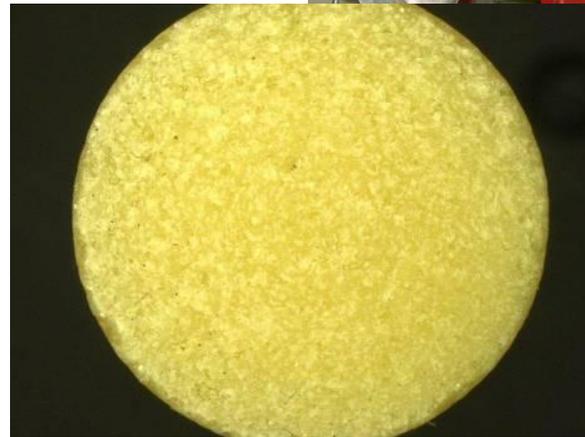
PAX-21 =162.5 cards
 Comp B ($\rho=1.69$) = 210 cards (19 kbar)

- ARDEC setback test

- collapses a planar air gap against an explosive sample such that the pressure-time history in the gap mimics what would occur if explosive inside a warhead broke free of the walls at maximum G's and set back on the gap.

- IMX-104 Results

- NO GO
- 18,000 G @ 217.9 (max) mills gap



PAX-21: GO @ 12,000G, Gap = 88.5 mills

Comp B: GO @ 12,000G, Gap = 124.8 mills

VARIATION OF PROPERTIES WITH AGE

70° C

	DSC (°C)	ERL Impact (cm)	BAM Friction (N)	ESD (J)	LSGT (# of cards)
Month 0	Peak: 224.9	114.4	160 no rxn 168 rxn	No rxn @ 0.25	106 – 124.5
Month 1	Peak: 228.6	> 125.9	216 no rxn 240 rxn	No rxn @ 0.25	NR
Month 2	Peak: 229.2	> 125.9	192 no rxn 216 rxn	No rxn @ 0.25	NR
Month 3	Peak: 234.8	> 125.9	216 no rxn 240 rxn	No rxn @ 0.25	135
Month 4	Peak: 229.7	> 125.9	192 no rxn 216 rxn	No rxn @ 0.25	NR
Month 6	Peak: 228.1	> 125.9	192 no rxn 216 rxn	No rxn @ 0.25	129.5

VARIATION OF PROPERTIES WITH AGE (continued)



60° C

	DSC (°C)	ERL Impact (cm)	BAM Friction (N)	ESD (J)	LSGT (# of cards)
Month 0	Peak: 224.9	114.4	160 no rxn 168 rxn	No rxn @ 0.25	106 – 124.5
Month 1	Peak: 232.9	> 125.9	180 no rxn 192 rxn	No rxn @ 0.25	NR
Month 2	Peak: 231.2	> 125.9	180 no rxn 192 rxn	No rxn @ 0.25	NR
Month 4	Peak: 228.3	> 125.9	216 no rxn 240 rxn	No rxn @ 0.25	133.5
Month 8	Peak: 221.4	> 125.9	216 no rxn 240 rxn	No rxn @ 0.25	124.5

25° C at 30% Relative Humidity

	DSC (°C)	ERL Impact (cm)	BAM Friction (N)	ESD (J)	LSGT (# of cards)
Month 0	Peak: 224.9	114.4	160 no rxn 168 rxn	No rxn @ 0.25	106 – 124.5
Month 12	Peak: 215.4	> 125.9	216 no rxn 240 rxn	No rxn @ 0.25	120.5

IMX-104 Detonation Velocity vs. Diameter

Pellet Diameter (in.)	Average Det. Vel. (mm/us)	Witness Plate Height (in.)	Average Dent (in.)
0.75	0	2	0
0.875	7.128	2	0.109
1	7.210	2	0.144
1.125	7.354	2	0.173
1.5	7.420	5	0.229
1.75	7.513	5	0.282
2	7.463	5	0.335
2.25	7.396	5	0.378
2.5	7.631	5	0.421



IMX-104 Fiber Optic Detonation Velocity

Detonation Velocity for Qualified Explosives

Formulation	Detonation Velocity (Km/s)
IMX-104 ¹	7.4
Comp B	7.98
PAX-21	6.7
PAX-41	7.68
PAX-48 ²	7.18
IMX-101 ³	6.9



Witness Plate Dents From FODV Test

All samples were tested at 3/4" diameter except: 1) 2" diameter, 2) 1" diameter, 3) 4" Cylinder Expansion Tube

- Determine failure threshold for the propagation of steady-state detonation

	Calculated Critical Diameter	Detonation Velocities
Shot 1	0.687"	7.27 & 7.28 mm/s along the streak (at roughly 0.90" D and 0.70" D)
Shot 2	0.691"	7.43 and 7.26 mm/us along the streak (at roughly 0.95" D and 0.70" D)



IMX-104 Tapered Rod



104 Various Diameter Pellets



Witness Plates for Critical Diameter Post-test

Critical Diameters for Qualified Explosives

Formulation	Critical Diameter (inches)
IMX-104	0.875
Comp B	0.169
PAX-21	0.45 - 0.5
PAX-41	<0.5
PAX-48	0.75 - 1
IMX-101	2.6

- The qualification test results indicate that IMX-104 meets and exceeds the requirements for Material Release Qualification Program.
- It is insensitive and its properties remain stable with age.
- This effort directly supports the PM-CAS ECP of IMX-104
 - M821A2, M889A1 & M889A2 81mm Mortars
 - M720A1, M768 & M888 60mm Mortars
 - M933 & M934A1 120mm Mortars

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